(12) UK Patent Application (19) GB (11) 2 272 843 (13) A

(43) Date of A Publication 01.06.1994

(21) Application No 9323040.7

(22) Date of Filing 09.11.1993

(30) Priority Data
(31) 9223579 (32) 11.11.1992 (33) GB
9307142 06.04.1993

(51) INT CL[5]
B01D 29/11

(52) UK CL (Edition M)
B1D DDPA DDQA

(56) Documents Cited
GB 1208567 A WO 85/05286 A1 US 4819722 A

(58) Field of Search
UK CL (Edition M) B1D DDPA DDQA, B1T TDPA TDQA
INT CL[5] B01D 29/00 29/01 29/11
ONLINE DATABASE:WPI

(71) Applicant(s)
Pall Corporation

(Incorporated in USA - New York)

2200 Northern Boulevard, East Hills, New York, New York 11548, United States of America

(72) Inventor(s)
Michael Ernest Grimes
George Clive Jenkins
Simon Victor Madgwick

(74) Agent and/or Address for Service
Mathisen Macara & Co
The Coach House, 6-8 Swakeleys Road, Ickenham, UXBRIDGE, Middlesex, UB10 8BZ, United Kingdom

(54) Filter elements

(57) A tubular metal filter sleeve 34 is placed on a polymeric end cap 31 and heated by induction coil 24 so that it melts its way into the cap and bonds thereto. The degree of penetration is limited by projections 39 on a split ring 37 clamped round the sleeve. Argon or an argon-hydrogen reducing mixture fed through passage 27 prevents the heated metal from oxidising. The sleeve 34 may be stainless steel sintered powder or fibres or sintered mesh. The end cap 31 may be polyester, polypropylene or polyetheretherketone. A somewhat similar apparatus (Fig. 3) enables the metal sleeve to be separated from the end cap after use, so that a new end cap can be fitted. The sleeve may be pleated or not.

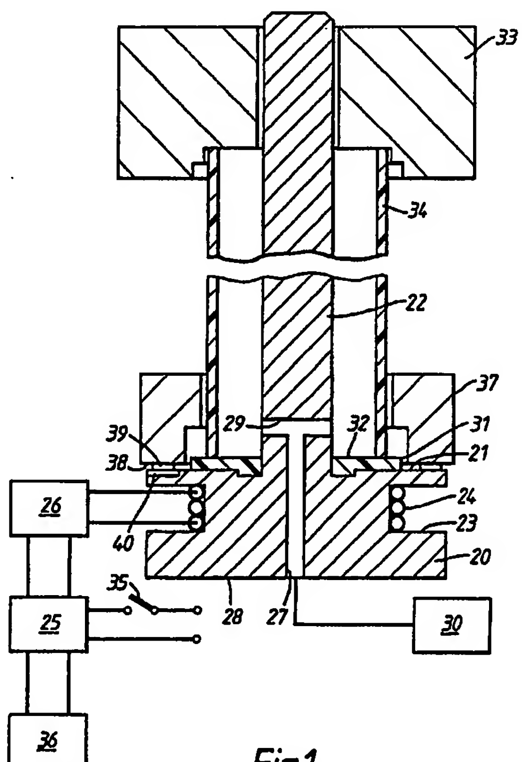

Fig.1

GB 2 272 843 A

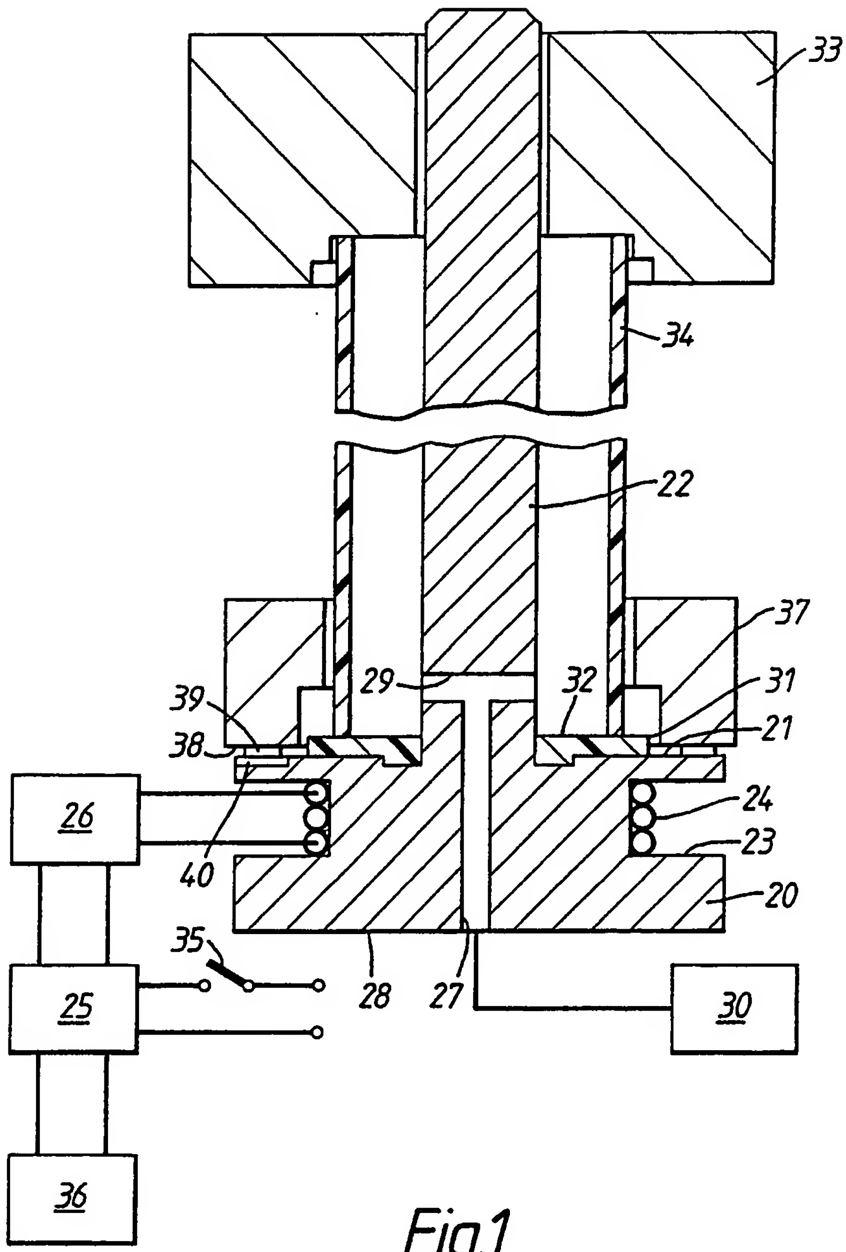

Fig.1

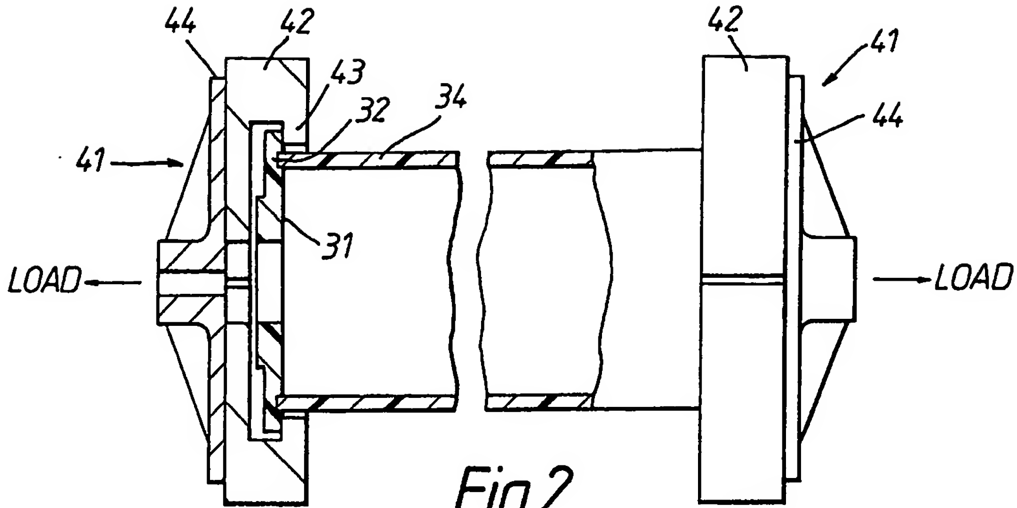
44
42
43
32
34
41
31
LOAD
42
41
44
LOAD

Fig.2

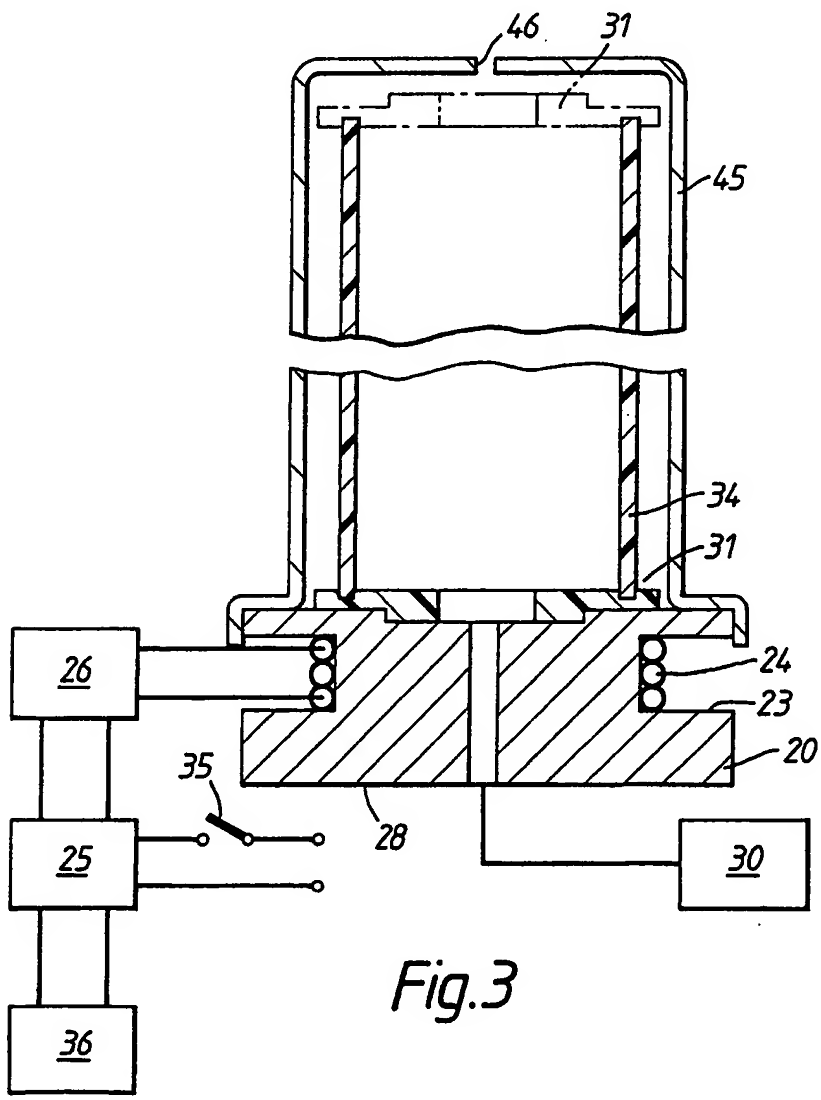
46
31
45
34
31
26
24
23
20
35
28
25
30
36

Fig.3

FILTER ELEMENTS

The invention relates to filter elements and in particular to filter elements in which the filter media are metallic.

Many filter elements use filter media that are metallic - for example stainless steel meshes, stainless steel fibres or stainless steel powders. There are also filter media made of other metals such as bronze or aluminium. In use, these filter media can be formed into a tubular (e.g. cylindrical) configuration (with or without pleating) and are incorporated in a housing that defines a fluid path through the filter media.

Such media enable filtration in extremely hazardous environments, for example at extreme temperatures with highly corrosive fluids or with highly viscous fluids. Stainless steel in particular offers excellent mechanical and corrosion resisting properties and can be repeatedly cleaned and re-used.

In order to allow such filter media to be incorporated in the housing and to define the required flow path, such metal media are provided with metal end caps which cover the end of the media, engage cooperating parts in the housing and define the necessary flow path.

Such metal end caps are attached to the metal media by a welding, brazing or glueing process to form a filter element. They have, however, a number of disadvantages.

Where a welding process is used, the metal medium often requires swaging or consolidating during the attachment of the metal end caps. This can damage the media or create debris. In addition, after attachment of metal end caps, the filter element may require cleaning and passivating. Further, metal end caps cannot be readily removed to allow the media to be recovered and/or cleaned. In addition, filter elements are weighty and, where welding is used, non-flow areas can be created at the junction between the end caps and the filter medium which interfere with filtrate flow or flow of cleaning materials. Further, metal end caps are not flexible and therefore do not readily flex to take up tolerances when fitted in a housing.

According to a first aspect of the invention, there is provided a filter assembly comprising a filter medium of metal and a support of a polymeric material connected to an edge of the filter medium by an inductive heating process.

According to a second aspect of the invention, there is provided a method of manufacturing a filter element

comprising surrounding a metallic filter medium and a support of a polymeric material with an inert or reducing atmosphere, heating at least an edge of the filter medium to melt the support, and then inserting the heated edge of the filter medium into the melted polymeric material of the support to connect the filter medium and the support.

According to a third aspect of the invention, there is provided apparatus for connecting a polymeric support to a metal filter medium comprising a base having a surface for carrying a support, an induction heater carried by said base for heating the metal filter medium and a guide for guiding a metal filter medium so that an edge of the filter medium contacts the support in a predetermined disposition and is inserted into the support when the support has been melted by the heated metal filter medium.

End caps of plastics materials such as polypropylene or polyester are known, primarily for use with plastics filter media as described in WO 85/05286. However, there are also proposals for using such end caps with metallic media. For example, GB-A-1151592 discloses the use of polyurethane materials for end capping metallic media. GB-A-680211 discloses the use of thermosetting synthetic resins with media including a metal gauze. US-A-4819722 discloses the connection of a metal well screen to a

polypropylene end fitting. GB-A-1208567 discloses a filter medium including metallic elements and a polyurethane end cap.

The plastics materials from which the disclosed end caps or end fitting are made have melting points at about 150^{o}C to 250^{o}C (polypropylene 155^{o}C to 165^{o}C, polyester 225^{o}C to 255^{o}C). This places an upper limit on the temperature of the environment in which such filters can be used. Although the metallic filter media can endure much higher temperatures, the plastics end caps have necessitated much lower temperature limits. For higher temperature environments, metal end caps have been used, with the problems outlined above.

Plastics materials are available which have higher melting points (for example above 340^{o}C) but it has not proved possible to connect successfully end caps of such materials to metallic media.

In addition, there is the problem, even with lower melting point polymeric materials, such as polypropylene or polyester, that, when connected to metallic filter media by heating the media and when the media are of signficiant size, so necessitating lengthy heating of the media, surface deterioration of the media can be caused by such heating.

According to a fourth aspect of the invention, there is provided a filter element comprising a filter medium of metal and a support of a polymeric material connected to an edge of the filter medium in an inert or reducing atmosphere.

According to a fifth aspect of the invention, there is provided a method of manufacturing a filter element comprising surrounding a metallic filter medium and a support of a polymeric material with an inert or reducing atmosphere, heating at least an edge of the filter medium to melt the support, and then inserting the heated edge of the filter medium into the melted polymeric material to connect the filter medium and the support.

According to a sixth aspect of the invention, there is provided apparatus for connecting a polymeric support to a metal filter medium comprising a base having a surface for carrying a support, a heater carried by said base for heating at least an edge of the metal filter medium, means for providing an inert or reducing atmosphere in the zone of said edge and a guide for guiding a metal filter medium so that said edge of the filter medium contacts the support in a predetermined disposition and is inserted into the support when the support has been melted by the heated metal filter medium.

The following is a more detailed description of some embodiments of the invention, by way of example, reference being made to the accompanying drawings in which:-

Figure 1 is a schematic cross-sectional view of a jig assembly for connecting end caps of a plastics material to a filter medium of metallic material,

Figure 2 is a schematic side elevation, partially in section, of a jig assembly for testing the tensile strength of the connections between the end caps and the filter medium of filter elements prepared using the jig assembly of Figure 1,

Figure 3 is a cross-sectional view of an assembly for un-end-capping filter units prepared using the assembly of Figure 1.

In the exemplified embodiments of the invention, end caps prepared from three different materials are connected to media made from three different materials by a connection method to be described. The filter elements so produced are bubble-point tested, integrity-tested and tensile-tested. The integrity of the filter elements after re-use is also tested by un-end capping and re-end capping prior to testing. These various features will now be described in detail.

THE END CAP MATERIALS

End caps were formed from three different materials; polypropylene, polyester and polyetheretherketone (PEEK).

The polypropylene was a commercial grade polypropylene sold by Exxon Corporation under the trade designation ESCORENE (PP1074). This material has a melt flow of 20. Melt flow is a guide to viscosity where a lower value indicates a higher viscosity and hence a greater resistance to flow.

The polyester was a commercially available polyester sold by Exxon Corporation under the trade name CELANEX 1700A. It has a melt flow of 5.

The PEEK is sold by Imperial Chemical Industries under the designation 450G. There are, however, available from ICI other grades of PEEK which may be suitable for use in the method to be described. For example, there are PEEK grades 150GL300, 450GL30, 150CA30 and 450CA30 that may be suitable. The designation GL indicates that the PEEK has a 30% by volume glass fibre reinforcement and CA indicates to the presence of a 30% by volume carbon fibre reinforcement. The 150 grade has a lower viscosity than the 450 grade.

The deflection temperatures of these grades are as given in Table 1 below.

TABLE 1

PEEK GRADE	DEFLECTION TEMP.	TEST PRESSURE
450G	160°C	18 bar
150GL30	300°C	18 bar
450GL30	315°C	18 bar
150CA30	300°C	18 bar
450CA30	315°C	18 bar

The "deflection temperature" in Table 1 is the temperature at which the designated PEEK grade will deflect significantly. The "pressure" is a standard test pressure at which the PEEK deflection temperature is measured.

MEDIA MATERIALS

Three materials were used for the filter medium; a porous sintered stainless steel, a sintered woven stainless steel wire mesh and a mat of sintered interwoven fine stainless steel fibres.

The media made of porous sintered stainless steel was that sold by Pall Corporation under the trade mark PSS. This is made by sintering pre-alloyed stainless steel powder. No binders are used during the manufacturing process thus avoiding any increase in carbon content. The sintering is performed without any pressure to avoid reductions in

permeability. The medium is highly porous with up to 50% pore volume and retains the full corrosion and temperature resistant properties of the alloy.

PSS is graded according to its removal rating measured by a modified OSU F2 efficiency test using standard AC dusts in water with removal efficiency determined by particle count. These ratings are expressed for a range of β values. A β value is the ratio of the number of particles greater than a given size in the dust/water mixture fed to the media compared to those of the same size or larger in the dust/water mixture leaving the media. PSS Grade PH has a rating of 15 micrometers at β=100 (99%).

The sintered woven stainless steel wire mesh used was that sold by Pall Corporation under the trade mark RIGIMESH. The medium is made from woven stainless steel wire mesh which has been upgraded by sintering. This produces a very strong material with the wires effectively welded at their intersections. The sintering process also ensures the integrity of pore size under arduous operating conditions.

RIGIMESH has a removal rating measured by the diameter of the largest hard spherical particle that will pass through

the media under specified test conditions. This is an indication of the largest opening in the filter element. RIGIMESH Grade RMA has a rating of 45 micrometers.

The media sintered interwoven fine stainless steel fibres was that sold by Pall Corporation under the trade mark PFM. This is a mat of random interwoven fine metal fibres that are sintered to weld together the fibres at their points of contact. Up to 85% of the volume is interconnecting voids. PFM is graded with reference to its removal rating as measured by a modified OSU F2 efficiency test using AC Fine Test Dust in oil with the removal efficiency determined by particle count. The ratings are expressed at a β value (or values) which is the ratio of the number of particles greater than a given size in the dust/oil mixture before filtration compared to those of the same size or larger in the dust/oil mixture after filtration. PFM Grade PFM 20 has a rating of 22 micrometers at a β value of 100 (99%).

In all cases, the filter medium is formed into a tube (e.g. a cylinder) which may be continuous or may include an edge weld. The filter medium may be pleated or may be un-pleated.

CONNECTION METHOD

The connection between the end caps and the media is performed using the jig assembly shown in Figure 1. The jig assembly comprises a generally cylindrical base 20 having an upper surface 21 from which projects a guide rod 22 with its axis coaxial to the axis of the base 20. The base 20 and the guide rod 22 are made from nylon.

The outer curved surface of the base 20 is provided with an annular groove 23 which contains a water-cooled work coil 24 of a high frequency induction machine 25. The machine 25 has a maximum rating of 3kW and is controlled by a ten-turn potentiometer 26 capable of adjusting the power output between 0-100%. The HF machine 25 has an on/off switch 35 controlling the duration of heating. It has a timer 36 by which the duration of heating can also be controlled.

A passage 27 leads from the undersurface 28 of the base 20 to a cross-passage 29 emerging at diametrically opposite sides of the guide rod 22 towards the lower end of the guide rod 22. The passage 27 is connected to a source of argon 30.

The upper surface 21 of the base 20, and the guide rod 22 are configured so that an end cap 31 can pass over the

guide rod 22 and rest on the upper surface 21 with an inner surface 32 of the end cap 31 generally horizontal.

The guide rod 22 also guides an annular guide weight 33 which rests on the upper end of a cylindrical filter medium 34 whose lower end rests on the inner surface 32 of the end cap 31. The weight is 4kg, but any other suitable weight may be used.

A split ring 37 is clamped on to the filter medium 34 towards its lower end and has an annular under surface 38 provided with four equi-angularly spaced dogs 39. The upper surface 21 of the base 20 is provided with four equi-angularly spaced recesses 40 in radial alignment with the dogs 39. The dogs 39 and the recesses 40 together control the depth of penetration of the filter medium 34 into the end cap 31 in a manner to be described below. This depth is 1.5mm although it may be varied as required to give a particular penetration of the filter medium 34 into the end cap 31.

In use, the jig assembly is operated as follows:

First, an end cap 31 is placed on the upper surface 21 of the base 20. The filter medium 34 is placed on the end cap and the split ring 37 clamped around the filter medium

34 with the dogs 39 contacting the surface 21 to fix the axial position of the split ring 37 on the filter medium 34. The split ring 37 and the filter medium 34 are then rotated together until the dogs 39 are aligned with the recesses 40.

The guide weight 33 is then placed on the upper end of the filter medium 34. The argon source 30 is then switched on and the HF machine 25 is switched on for a pre-determined time and at a pre-determined power setting and current, depending on the materials involved. These will be discussed in greater detail below. The HF Machine 25 heats the edge of the medium 34 which in turn melts the end cap 31. As the end cap 31 is melted, the guide weight 33 forces the end of the filter element 34 into the end cap 31. The depth of penetration is controlled by the dogs 39 contacting the bases of the associated recesses 40.

The use of the inert atmosphere has the very significant advantage of preventing surface deterioration of the metallic media during the joining process. For example, when the end cap is of PEEK it may, as indicated above, be necessary to heat the end cap to a temperature well in excess of 300°C, and possibly to 400°C to 500°C, in order to effect the joining process. At these temperatures, the metallic media can suffer surface deterioration such as oxidisation which may affect adversely the performance of the filter.

Even where the end cap 31 is of a lower melting point material, the reducing atmosphere has the advantage of reducing or eliminating surface deterioration of the metallic media that arises when large elements are being end capped, as a result of the length of time for which such media must be heated to allow end cap connection.

Of course, the atmosphere need not be argon, it could be any other suitable gas or gas mixture. The atmosphere may also be a reducing atmosphere such as hydrogen or a mixture of hydrogen in argon (5% hydrogen in argon by volume), which will not only prevent surface deterioration such as oxidation, but will also remove any oxides or carbon impurities present during the end capping process.

When the HF machine 25 has stopped, the source of argon 30 is switched off. The guide weight 33 is then removed and the split ring 37 unclamped. The joined end cap 31 and filter medium 34 are then removed and the steps are repeated to connect a second end cap 31 to the other end of the filter medium 34.

It may be necessary to dry PEEK and polyester end caps before processing to remove any absorbed moisture. PEEK end caps 31 may require 3 hours drying at 150°C and polyester end caps 31 10 hours at 121°C. The dried end

caps 31 should be used within three hours of drying to avoid moisture absorption before assembly.

The power output of the HF machine 25 and the duration of the power output must be adjusted to take account of the materials of the end cap 31 and the medium 34. When using high power for a short time, the medium 34 will quickly reach the desired temperature to melt and penetrate the end cap 31 without absorbing a great deal of heat. This is due to the very local area of induction: only in the surface of the medium 34 adjacent to the work coil 24. The polymeric end cap 31 is not heated directly by the work coil 24 as heat can only be induced in conductive materials. Similarly, the jig assembly, being constructed of nylon, is unaffected by inducting heating. If greater penetration of heat is required, then a longer duration allows heat to travel by conduction. When the desired temperature is reached, however, significantly more heat will have been absorbed and the medium 34 will take longer to cool.

Table 2 below gives the power and duration for the various combinations of cap material and medium material exemplified above. It will be appreciated that other powers and durations may be necessary for other combinations of cap material and medium material.

TABLE 2

CAP MATERIAL	MEDIA (All Trade Marks)	% POWER	TIME(SECS) (approx)
Polypropylene	PSS(PH)	40	8
Polypropylene	Rigimesh(RMA)	60	15
Polypropylene	PFM20	60	15
Polyester	PSS(PH)	50	9
Polyester	Rigimesh(RMA)	60	17
Polyester	PFM20	60	17
Peek	PSS(PH)	50	11
Peek	Rigimesh(RMA)	60	27
Peek	PFM20	60	27

It will be seen that the greatest heating time is required by PEEK end caps 31 with filter media 34 of RIGIMESH or PFM. It is possible to reduce this time to approximately 18 seconds using 80% power but the reduced time does not generally allow the PEEK to flow evenly into the filter media 34. It might be possible to overcome this with an easy-flow grade of PEEK of the kind discussed above.

It will be appreciated, of course, that the geometry of the work coil 24 and the number of its turns will be selected to give optimum performance. The geometry of the work coil 24 should follow closely the specimen profile. As small as possible gap between the work coil 24 and the end cap 31 is preferred to give the greatest efficiency by increasing the flux concentration. Since the flux generated is proportional to the number of turns in the work coil, it is desirable to wind as many turns as

possible for the given area of upper surface 21 while maintaining an inside diameter compatible with the desired coupling with the media 34.

BUBBLE POINT TESTING

The filter elements prepared as described above using the combinations of Table 2 were tested for the integrity of their connection using a bubble point test. In such a test, the filter element is submerged in a bath of isopropyl alcohol ("IPA") to wet out all the pores. Pressure is then applied to the interior of the structure and the pressure required for the first or initial bubble of air to appear on the exterior surface of the element is recorded.

For the porous medium alone, the bubble point (i.e. the pressure at which the first or initial bubble of air appears) is related to the pore size of the medium. If the connection between the end caps 31 and the medium 34 leaves gaps or pathways that are larger than the pore size of the medium, then the integrity of the element will be compromised.

The results of the bubble point tests for the element configurations of Table 2 were equivalent to or better than those for elements with metal end caps welded to metal media.

INTEGRITY TESTING

The bubble point test described above is one measure of the integrity of the joint between the end cap 31 and the filter element 34. It does not, however, simulate accurately an "in-service" condition of a filter element. In order better to simulate such conditions, it is necessary to maintain a significant pressure differential across the filter elements at an elevated temperature. The integrity of the joint after repeated replacement of the end caps 31 is also tested in this manner.

In order to conduct such a test for the filter elements described above, a sample of a filter element of each of the kinds described above was treated in the following way. First, after initial end capping, the end caps 31 were removed and the filter element 34 provided with new end caps 31 which were then removed and replaced by further new end caps 31. The surface of the filter medium 31 was sealed with a shrink wrap tube of the kind sold under the trade mark EMS2 101.6 of Egerton Power Products.

Each filter element was then held at a temperature given below in Table 3 with a pressure differential between the interior and exterior of the filter element as given in Table 3 below.

TABLE 3

CAP/MEDIA COMBINATION	TEMPERATURE	PRESSURE DIFFERENTIAL
Peek/Rigimesh	232^{o}C	9.0 bar
Polyester/PFM	154^{o}C	4.5 bar
Polypropylene/PSS	100^{o}C	3.2 bar

After the 24 hour temperature/pressure test, all the filter elements were bubble tested as described above. It was found that they all had bubble points equivalent to or better than those for elements with metal end caps welded to metal media.

TENSILE TESTING

Certain of the filter elements made as exemplified above were tested to determine the load which must be applied to the end cap 31 in the direction of the axis of the filter element required to cause failure in the filter element. This failure is either failure of the cap 31 itself or failure of the join between the end cap 31 and the filter medium 34.

The tests were conducted using the jig assembly of Figure 2. This jig comprises two couplings 41 arranged coaxially with the axis of the filter element and engaging respective end caps 31 of the filter element. Each coupling 41 comprises a split retaining ring 42 which receives the associated end cap 31 and which has a flange

43 engaging the peripheral edge of the inner surface 32 of the associated end cap 31. Each split retaining ring 42 is connected to an attachment member 44 which, in turn, is connected to the load. The load is applied along the common axes of the couplings 41 and the filter element.

The results of this test are given in Table 4 below.

TABLE 4

CAP AND MEDIA COMBINATION	TENSILE STRENGTH		TYPE OF FAILURE	
	KN	TONNE	CAP	JOIN
Polypropylene-PSS	5.02	0.51		*
Polypropylene-PSS	4.33	0.44		*
Polypropylene-Rigimesh	3.43	0.35	*	
Polypropylene-Rigimesh	3.83	0.39		*
Polypropylene-PFM	5.30	0.54		*
Polypropylene-PFM	7.41	0.76	*	
Polyester-PSS	7.93	0.81		*
Polyester-Rigimesh	5.73	0.58		*
PEEK-PSS	11.86	1.21	*	

RE-USING ELEMENTS

Stainless steel filter media 34 can be chemically cleaned without affecting either PEEK or polypropylene end caps 31. Thus such filter elements can be cleaned and re-used as is known in the art. Polyester end caps 31 are cleanable but have a reduced range of chemical compatability when compared to PEEK and polypropylene capped elements.

In addition, the end caps 31 can be removed and replaced with new end caps. Polyester end caps 31 can be dissolved 100% by chemicals. Polypropylene end caps 31 can be removed by melting and burning. PEEK end caps 31 cannot be easily removed either chemically or by burning.

All end caps however can be removed by the following procedure utilizing a modified form of the jig assembly of Figure 1. This modified jig assembly is shown in Figure 3 and parts common to the assembly of Figure 1 and Figure 3 are given the same reference numerals and will not be described in detail.

The assembly of Figure 3 omits the guide rod 22 and the guide weight 33. The argon inlet passage 27 thus emerges at the upper surface 21 of the base 20. A cylindrical enclosure 45 closed at its upper end has an open lower end which fits on to the upper surface 21 of the base to provide a chamber for enclosing a filter element.

In use, one end cap 31 of a filter element is placed on the upper surface 21 of the base 20. The enclosure 45 is then placed over the element and fitted on to the upper surface 21.

The argon source 30 is then turned on to fill the enclosure 45 with argon to purge any air in the enclosure 45 out through the vent 46. The HF machine 25 is then turned on for a time sufficient to melt the joint between the end cap 31 and the filter medium 34 after which it is turned off. The inert atmosphere again acts to prevent surface deterioration of the filter medium 34. The source of argon 30 is then turned off and the enclosure 45 removed.

The end cap 31 can then be separated from the filter medium 34, if necessary being dislodged with a suitable tool. The procedure is then repeated for the other end cap 31.

After the end caps 31 have been removed, new end caps may be connected to the filter medium 34 as described above with reference to Figure 1. As discussed above under INTEGRITY TESTING, this reconnection can be achieved without affecting adversely the bubble point performance of the filter element. After the end caps 31 have been removed, small deposits of polymer may remain, particularly on pleated media. This does not affect re-end capping provided the same type of polymer end cap is used.

It will be appreciated that materials other than those described above may be used. For example polyethersulphone (PES) may be used. In addition, the configuration of the end caps 31 and the filter media 34 may be other than as described above. The end caps 31 may be in the form of adapters or bombfin end caps with the shape of the jig assembly of Figure 1 being adapted accordingly.

The constructions described above with reference to the drawings have a number of advantages. These are as follows:-

1. The use of an inert or reducing atmosphere reduces or prevents surface deterioration of the metallic medium, particularly at higher temperatures and/or during the connection of large filter media to end caps.

2. The end caps 31 can be securely attached to the filter medium 34 without swaging or consolidating the medium. This avoids possible damage (as measured by bubble point) and/or creation of debris during manufacture.

3. The filter media 34 can be fully passivated and cleaned prior to fitting of the end caps, since no metal welding process is necessary.

4. The end caps 31 can be removed from the filter media 34 so allowing the media to be recovered or cleaned and replaced with new end caps 31.

5. The filter media 34 can be better cleaned without removing the end caps because consolidation of the edges of the media is eliminated and thus the element can be recycled.

6. Moulding plastics caps 31 uses less labour than machining from solid and so plastics end caps are less expensive.

7. Moulded plastics end caps are inherently less expensive than machining from solid because less material is used.

8. Since the plastics end caps 31 are lighter than similar stainless steel end caps, the weight of the filter element is reduced.

9. The design will remove dead (non-flow) areas at the junction of the end caps 31 and the filter media 34. This prevents blockage of filtrate flow which could lead to quantities of filter fluid (or cleaning materials) being held within the filter media 34 and stagnating.

10. The end caps 31 are inherently flexible and thus can adapted to take up manufacturing tolerances between the filter element and associated housing.

11. A given injection moulded end cap can be used for more than one type of filter element since a specific size of recess or locator is not required for the assembly process.

It will be appreciated that the invention may be applied to any filter medium cylindrical or otherwise made of metal. This includes filter media of other metals such as bronze or aluminium. Any edge of such media can be connected to a polymer end cap as described above with reference to the drawings. Indeed, the connection need not be to an end cap, the connection could be to any polymer support. Any suitable thermoplastic material can be used for the end caps 31 or other support and will in practice be selected in accordance with the conditions of use. The element need not be heated as described above, it could be heated in any suitable way, for example, by one of the following:-

1. Heating the whole metal element to a temperature of, say, about 260^{o} C and then inserting an edge of the media into a support (which may itself be pre-heated).

2. Heating the metal element and then inserting the element into a partially molten support.

3. Heating the metal element using a microwave source.

4. Connecting the element and the support by a spin welding technique.

5. Heating the metal element directly or with infra-red radiation and then inserting the element into the support (which may itself be pre-heated).

CLAIMS

1. A filter element comprising a filter medium of metal and a support of a polymeric material connected to an edge of the filter medium by an inductive heating process.

2. A filter element comprising a filter medium of metal and a support of a polymeric material connected to an edge of the filter medium in an inert or reducing atmosphere.

3. A filter element according to claim 1 or claim 2 wherein the support is an end cap and said filter medium is cylindrical, an end of the filter medium being connected to the end cap.

4. A filter element according to any one of claims 1 to 3 wherein the end cap is of polyester, polypropylene or polyetheretherketone.

5. A filter element according to any one of claims 1 to 4 wherein the filter medium is of sintered metal powder or of woven wire mesh or of interwoven fine metal fibres.

6. A filter element substantially as hereinbefore described with reference to Figures 1 to 3 of the accompanying drawings.

7. A method of manufacturing a filter element comprising surrounding a metallic filter medium and a support of a polymeric material with an inert or reducing atmosphere, heating at least an edge of the filter medium to melt the support, and then inserting the heated edge of the filter medium into the melted polymeric material of the support to connect the filter medium and the support.

8. A method of manufacturing a filter element comprising contacting an edge of a metal filter medium with a support of a polymeric material and then heating the filter medium by an inductive heating process to cause the melting of at least a portion of said support and then inserting the edge of the filter medium into the melted support to connect the edge and the support.

9. A method according to claim 7 wherein said heating is an inductive heating process.

10. A method according to claim 8 or claim 9 and comprising placing said edge of the filter medium in contact with said support, applying a force urging the support and the filter medium together and then heating inductively the filter medium so that said force urges the edge of the filter medium into the molten support.

11. A method according to any one of claims 7 to 10 and further comprising controlling the depth of insertion of the filter medium into the support so that said depth is a predetermined depth which is less than the thickness of the support at the point of insertion.

12. A method according to any one of claims 7 to 11 wherein said support is an end cap and said filter medium is cylindrical, an end of the filter medium forming said edge.

13. A method according to any one of claims 7 to 12 and comprising melting a support connected to a filter medium, removing the support from connection with the filter medium and then connecting a further support to the metal filter medium in the same manner as the connection of said first mentioned support.

14. A method of manufacturing a filter element substantially as hereinbefore described with reference to the accompanying drawings.

15. Apparatus for connecting a polymeric support to a metal filter medium comprising a base having a surface for carrying a support, a heater carried by said base for heating at least an edge of a metal filter medium, means for providing an inert or reducing atmosphere in the zone

of said edge and a guide for guiding a metal filter medium so that said edge of the filter medium contacts the support in a predetermined disposition and is inserted into the support when the support has been melted by the heated metal filter medium.

16. Apparatus for connecting a polymeric support to a metal filter medium comprising a base having a surface for carrying a support, an induction heater carried by said base for heating the metal filter medium and a guide for guiding a metal filter medium so that an edge of the filter medium contacts the support in a predetermined disposition and is inserted into the support when the support has been melted by the heated metal filter medium.

17. Apparatus according to claim 16 wherein said means for providing an inert or reducing atmosphere comprise a passage provided in said base for supplying an inert or reducing gas to the interior of the filter medium.

18. Apparatus according to claim 15 wherein said heater is an induction heater.

19. Apparatus according to any one of claims 15 to 18 wherein the filter medium is cylindrical with said edge being formed by an end of said medium and said guide

comprises an elongate rod which projects from said base and which extends through the interior of a cylindrical filter medium carried thereby.

20. Apparatus according to any one of claims 15 to 19 wherein means are provided for urging an edge of a filter medium into contact with a support carried by said base to urge said edge into the support when the support has been melted by the filter medium.

21. Apparatus according to claim 20 wherein said urging means comprises a weight for contacting an edge of the filter medium opposite said edge of the filter medium contacting the support.

22. Apparatus according to any one of claims 15 to 21 wherein means are provided for limiting the depth to which the filter medium is inserted into the support when the support has been melted by the filter medium.

23. Apparatus according to claim 22 wherein filter medium is cylindrical and an end of said medium forms said edge, said limiting means comprising a collar for attachment to the cylindrical filter medium, said collar having a surface which, in use, is adjacent said support-carrying surface of the base, the collar having on said surface a plurality of projections in radial alignment with a

corresponding number of cooperating recesses in said base surface, the collar being attached to the filter medium with said projections contacting said base surface to fix the axial position of the collar along the filter element, the collar then being rotatable so that said projections are aligned with said recesses, the projections entering said recesses as the support is melted by the filter medium and the filter medium enters the support, the projections contacting the recesses after the filter medium has entered the support to a predetermined depth so determining said depth.

24. Apparatus for connecting a polymeric support to a metal filter medium substantially as hereinbefore described with reference to the accompanying drawings.

Amendments to the claims
have been filed as follows

1. A filter element comprising a filter medium of metal and a support of a polymeric material connected to an edge of the filter medium by an inductive heating process.

2. A filter element according to claim 1 wherein said support of a polymeric material is connected to an edge of the filter medium in an inert or reducing atmosphere.

3. A filter element according to claim 1 or claim 2 wherein the support is an end cap and said filter medium is cylindrical, an end of the filter medium being connected to the end cap.

4. A filter element according to any one of claims 1 to 3 wherein the end cap is of polyester, polypropylene or polyetheretherketone.

5. A filter element according to any one of claims 1 to 4 wherein the filter medium is of sintered metal powder or of woven wire mesh or of interwoven fine metal fibres.

6. A filter element substantially as hereinbefore described with reference to Figures 1 to 3 of the accompanying drawings.

7. A method of manufacturing a filter element comprising contacting an edge of a metal filter medium with a support of a polymeric material and then heating the filter medium by an inductive heating process to cause the melting of at least a portion of said support and then inserting the edge of the filter medium into the melted support to connect the edge and the support.

8. A method according to claim 7 and comprising surrounding a metallic filter medium and a support of a polymeric material with an inert or reducing atmosphere during said heating.

9. A method according to claim 7 or claim 8 and comprising placing said edge of the filter medium in contact with said support, applying a force urging the support and the filter medium together and then heating inductively the filter medium so that said force urges the edge of the filter medium into the molten support.

10. A method according to any one of claims 7 to 9 and further comprising controlling the depth of insertion of the filter medium into the support so that said depth is a predetermined depth which is less than the thickness of the support at the point of insertion.

11. A method according to any one of claims 7 to 10 wherein said support is an end cap and said filter medium is cylindrical, an end of the filter medium forming said edge.

12. A method according to any one of claims 7 to 11 and comprising melting a support connected to a filter medium, removing the support from connection with the filter medium and then connecting a further support to the metal filter medium in the same manner as the connection of said first mentioned support.

13. A method of manufacturing a filter element substantially as hereinbefore described with reference to the accompanying drawings.

14. Apparatus for connecting a polymeric support to a metal filter medium comprising a base having a surface for carrying a support, an induction heater carried by said base for heating the metal filter medium and a guide for guiding a metal filter medium so that an edge of the filter medium contacts the support in a predetermined disposition and is inserted into the support when the support has been melted by the heated metal filter medium.

15. Apparatus according to claim 14 and comprising means for providing an inert or reducing atmosphere in the zone of said edge during said heating.

16. Apparatus according to claim 15 wherein said means for providing an inert or reducing atmosphere comprise a passage provided in said base for supplying an inert or reducing gas to the interior of the filter medium.

17. Apparatus according to any one of claims 14 to 16 wherein the filter medium is cylindrical with said edge being formed by an end of said medium and said guide comprises an elongate rod which projects from said base and which extends through the interior of a cylindrical filter medium carried thereby.

18. Apparatus according to any one of claims 14 to 17 wherein means are provided for urging an edge of a filter medium into contact with a support carried by said base to urge said edge into the support when the support has been melted by the filter medium.

19. Apparatus according to claim 18 wherein said urging means comprises a weight for contacting an edge of the filter medium opposite said edge of the filter medium contacting the support.

20. Apparatus according to any one of claims 14 to 19 wherein means are provided for limiting the depth to which the filter medium is inserted into the support when the support has been melted by the filter medium.

21. Apparatus according to claim 20 wherein filter medium is cylindrical and an end of said medium forms said edge, said limiting means comprising a collar for attachment to the cylindrical filter medium, said collar having a surface which, in use, is adjacent said support-carrying surface of the base, the collar having on said surface a plurality of projections in radial alignment with a corresponding number of cooperating recesses in said base surface, the collar being attached to the filter medium with said projections contacting said base surface to fix the axial position of the collar along the filter element, the collar then being rotatable so that said projections are aligned with said recesses, the projections entering said recesses as the support is melted by the filter medium and the filter medium enters the support, the projections contacting the recesses after the filter medium has entered the support to a predetermined depth so determining said depth.

22. Apparatus for connecting a polymeric support to a metal filter medium substantially as hereinbefore described with reference to the accompanying drawings.

Patents Act 1977 **Ex iner's report to the Comptroller under Section 17** **(The Search report)**	Application number GB 9323040.7
Relevant Technical Fields (i) UK Cl (Ed.M) B1D (DDPA, DDQA); B1T (TDPA, TDQA) (ii) Int Cl (Ed.5) B01D (29/00, 29/01, 29/11)	Search Examiner R T HAINES Date of completion of Search 18 JANUARY 1994
Databases (see below) (i) UK Patent Office collections of GB, EP, WO and US patent specifications. (ii) ONLINE DATABASE: WPI	Documents considered relevant following a search in respect of Claims :- 1-24

Categories of documents

X: Document indicating lack of novelty or of inventive step.

Y: Document indicating lack of inventive step if combined with one or more other documents of the same category.

A: Document indicating technological background and/or state of the art.

P: Document published on or after the declared priority date but before the filing date of the present application.

E: Patent document published on or after, but with priority date earlier than, the filing date of the present application.

&: Member of the same patent family; corresponding document.

Category	Identity of document and relevant passages		Relevant to claim(s)
A	GB 1208567	(TECALEMIT ENG LTD)	1,2,3,5
X	US 4819722	(DALY)	1,3,4
A	WO 85/05286 A1	(VOKES LTD)	15,16

Databases:The UK Patent Office database comprises classified collections of GB, EP, WO and US patent specifications as outlined periodically in the Official Journal (Patents). The on-line databases considered for search are also listed periodically in the Official Journal (Patents).